What is claimed is:

1. A method in image guided radiosurgery for aligning the position of a treatment target relative to a radiosurgical beam generator during treatment, the method comprising:

a. generating a pre-treatment 3D scan showing the position of said target at treatment planning time;

b. generating a set of 2D reconstructed images from said 3D scan;

c. generating at near real time one or more 2D x-ray images of said target, wherein said x-ray images show the position of said target at a current time during treatment;

d. registering said reconstructed images with said x-ray images by computing a set of 3D transformation parameters that represent the change in position of target between said 3D scan and said x-ray images; and

e. in near real time, adjusting the relative position of said radiosurgical beam generator and said target by the amount prescribed by said 3D transformation parameters computed in step d; wherein said target is allowed six degrees of freedom of position.

2. A method in accordance with claim 1, wherein said 3D transformation parameters represent the difference between the position of the target at said treatment planning time, and the position of the target at said current time.

3. A method in accordance with claim 1, further comprising repeating steps c through e quasi-continuously during treatment, whereby one or more radiosurgical beams generated by said beam generator remain properly focused onto said target throughout said radiosurgical treatment.

4. A method in accordance with claim 1, further comprising the step of creating a treatment plan after step a and before step b.

5. A method in accordance with claim 4, wherein said treatment plan specifies the number,

intensity, and direction of said one or more radiosurgical beams that are required in order to administer a sufficient radiation dose to said target while minimizing the radiation to adjacent tissue.

6. A method in accordance with claim 1, further comprising the step of processing said x-ray images, after step c and before step d, so as to match the orientation, image size, and bit depth of said x-ray images with the orientation, image size, and bit depth of said reconstructed 2D images.

7. A method in accordance with claim 1, wherein said x-ray images are generated by transmitting one or more x-ray imaging beams through said target, said imaging beams having a known intensity, position, and angle; and
wherein said 2D reconstructed images are DRRs (digitally reconstructed radiographs) that represent the synthesized radiographic image of said target that would be obtained with said imaging beams at said known intensity and from said known positions and angles, if said target were positioned in accordance with said pre-treatment 3D scan.

8. A method in accordance with claim 1, wherein said 3D transformation parameters are 3D rigid body transformation parameters, and
wherein said 3D transformation parameters are represented by three translations and three rotations (x, y, z, r, p, w);
wherein x, y, z represent the translations of said target in the directions of three mutually orthogonal axes, respectively, and
wherein r, p, w represent three rotations (roll, pitch, yaw) about said three orthogonal axes.

9. A method in accordance with claim 1, wherein said x-ray images generated in step c comprises x-ray projection images that represent at least two orthogonal projections A and B of said target onto respective projection image planes, said x-ray projection images being formed by transmitting at least two x-ray imaging beams through said target and onto said respective image

planes, wherein each imaging beam is received by a respective x-ray camera after passing through said target.

10. A method in accordance with claim 9, wherein step b of generating reconstructed images comprises:
generating two sets of reconstructed images, one set for each of said projections A and B.

11. A method in accordance with claim 10, wherein step d of registering said reconstructed images with said x-ray images comprises:
A. individually registering each x-ray projection image A and B with their respective set of reconstructed images, by determining a separate set of transformation parameters for each projection x-ray image; and
B. combining the resulting parameters for each projection to obtain said 3D transformation parameters.

12. A method in accordance with claim 11, wherein said transformation parameters for each of said projections A and B are described by two out-of-plane rotational parameters (r_A, φ_A) and (r_B, φ_B) respectively, and by three in-plane transformation parameters (x_A, y_A, θ_A) and (x_B, y_B, θ_B), respectively.

13. A method in accordance with claim 12, wherein said 2D reconstructed images are DRRs, and wherein step b of generating said 2D reconstructed images comprises:
i) for each projection, specifying a set of rotation angles for each of said out-of-plane rotation parameters r and φ, N_r being the number of rotation angles for rotation parameter r, and Nφ being the number of rotation angles for rotation parameter φ; and
ii) generating two sets of DRRs, one set for each of said projections A and B;
wherein each set includes DRRs that correspond to different combinations of said out-of-plane rotation angles, so that the number of DRRs in each set is $N_r * N_\varphi$.

14. A method in accordance with claim 13, wherein the step of generating 2D reconstructed images further comprises the step of computing a set of in-plane rotated DRR images by performing a plurality of in-plane rotations on said DRRs, thereby creating a set of in-plane rotated reference DRRs for each projection.

15. A method in accordance with claim 14, wherein said step of creating reference DRRs is performed offline.

16. A method in accordance with claim 9, wherein the step of computing said 3D transformation parameters comprises:

i) individually computing the transformation parameters (x_A, y_A, θ_A) and (x_B, y_B, θ_B) for each projection image A and B; and

ii) combining the transformation parameters for projection A with the transformation parameters for projection B so as to obtain said 3D transformation parameters; and wherein said 3D transformation parameters are represented by three translations and three rotations (x, y, z, r, p, w).

17. A method in accordance with claim 16, wherein said 3D transformation parameters are related to the transformation parameters for projections A and B by the following relationship:

$$x = (x_A + x_B)/2,\ y = (y_A - y_B)/\sqrt{2},\ z = (y_A + y_B)/\sqrt{2},$$

$$r = (r_A + r_B)/2,\ p = (\theta_B - \theta_A)/\sqrt{2},\ w = (\theta_B + \theta_A)/\sqrt{2}$$

18. A method in accordance with claim 16, wherein the step of computing the transformation parameters for each projection comprises:

i) computing the in-plane transformation parameters using said in-plane rotated reference DRRs; and thereafter

ii) estimating the out-of-plane rotation parameters using the in-plane transformation parameters computed in step i) above; and thereafter

iii) iteratively refining said in-plane and out-of-plane transformation parameters, until said parameters converge to a sufficient accuracy.

19. A method according to claim 18, wherein step i) is performed using 3D multi-level matching, and a sum of absolute difference similarity measure.

20. A method according to claim 18, wherein step ii) is performed using a 1D search and a pattern intensity similarity measure.

21. A method according to claim 20, wherein step iii) comprises:

a) refining the in-plane translation parameters x and y using 2-D sub-pixel matching; and thereafter

b) refining the in-plane rotation parameter using 1-D interpolation,

22. A method in accordance with claim 1, wherein said 3D scan comprises at least one of: a CT scan, an MRI scan, an ultrasound scan, and a PET scan.

23. An image guided radiosurgical system for radiosurgical treatment of a target, the system comprising:

a. means for providing pre-treatment 3D scan data of said target;

b. a radiosurgical beam generator for generating at least one radiosurgical beam;

c. imaging means for generating one or more 2D x-ray images of said target in near real time, said imaging means including:

i) an imaging beam source for generating at least one imaging beam having a known intensity, and having a known position and angle relative to said target; and

ii) means for directing said imaging beam towards and through said target from said known location and angle, and at said known intensity;

iii) at least one image receiver for detecting the attenuated imaging beam after said beam has passed through said target; and

iv) an image processor for processing data from said image receiver to generate said x-ray image;

d. a controller, including:

i) means for generating at least one reconstructed 2D image of said target, based on said 3D scan data, and using said known intensity, location, and angle of said imaging beam;

ii) registration means for registering said reconstructed 2D image with said near real time x-ray image, said registration means including means for computing a set of 3D transformation parameters that represent the change in position of said target between said 3D scan and said near real time x-ray image; and

e. positioning means, responsive to said controller, for adjusting in near real time the relative position of said radiosurgical beam generator and said target by the amount prescribed by said 3D transformation parameters.

24. A system in accordance with claim 23, wherein said 2D reconstructed images comprises DRRs.

25. A system in accordance with claim 23, wherein said 3D scan data comprise at least one of CT scan data, MRI scan data, and PET scan data.

26. A system in accordance with claim 23, wherein said one or more 2D x-ray images of said target comprise x-ray projection images that represent at least two orthogonal projections A and B of said target onto respective projection image planes, and

wherein said x-ray projection images are formed by transmitting at least two x-ray imaging beams through said target and onto said respective image planes, wherein each imaging beam is received by a respective x-ray camera after passing through said target.

27. A system in accordance with claim 23, wherein said means for generating at least one reconstructed 2D image comprises means for generating two sets of reconstructed images, one set for each of said projections A and B.

28. A system in accordance with claim 23, wherein said registration means comprises:

A. means for individually registering each x-ray projection image A and B with their respective set of reconstructed images by determining a separate set of transformation parameters for each projection x-ray image; and

B. combining the resulting parameters for each projection to obtain said 3D transformation parameters.

29. A system in accordance with claim 28, wherein said transformation parameters for each of said projections A and B are described by two out-of-plane rotational parameters (r_A, φ_A) and (r_B, φ_B) respectively, and by three in-plane transformation parameters (x_A, y_A, θ_A) and (x_B, y_B, θ_B), respectively.

30. A system in accordance with claim 29, wherein said means for generating at least one reconstructed 2D image of said target comprises:

i) means for specifying, for each projection A and B, a set of rotation angles for each of said out-of-plane rotation parameters r and φ, wherein the number of rotation angles for rotation parameter r is Nr, and the number of rotation angles for rotation parameter φ is Nφ; and

ii) means for generating two sets of DRRs, one set for each of said projections A and B; wherein each set includes DRRs that correspond to different combinations of said out-of-plane rotation angles, so that the number of DRRs in each set is N_r*N_φ.